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Advanced Learning Techniques In Badminton At The Cahaya Muda Badminton Association

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Abstract
The research problem is the low smashing ability of badminton athletes at PB Cahaya Muda. Low smash accuracy is influenced by several factors, such as leg muscle explosiveness, hand-eye coordination, and arm muscle explosiveness. This study aims to reveal the direct and indirect effects, as well as the simultaneous effects between variables.This study is a quantitative associative study using a path analysis approach. The population in this study was all 55 badminton athletes at PB Cahaya Muda. The sample was taken using purposive sampling of 20 individuals. The data instruments were leg muscle explosiveness, vertical jump, hand-eye coordination using a hand-eye coordination test, arm muscle explosiveness using a one-hand medicine ball, and badminton smash accuracy. The data were analyzed using path analysis through structural model testing at $\alpha = 0.05$.The results of the hypothesis testing show: (1) there is a direct influence of leg muscle explosive power on the accuracy of badminton smashes (py1 = 0.435 or 18.92%), (2) there is a direct influence of hand eye coordination on the accuracy of badminton smashes (py2 = 0.057 or 0.27%), (3) there is a direct influence of arm muscle explosive power on the accuracy of badminton smashes (py3 = 0.564 or 31.08%), (4) there is an indirect influence of arm muscle explosive power on the accuracy of badminton smashes (p31.py3 = 0.886 or 78.49%), (5) there is an indirect influence of hand eye coordination on the accuracy of badminton smashes (p32.py3 = 0.0345 total influence 3.49%), and (6) there is an influence of leg muscle explosive power, hand eye coordination and arm muscle explosive power simultaneously on the accuracy of badminton smashes (Rsquare = 0.886 or 88.6%).

INTRODUCTION

Badminton is a dynamic racket sport that demands a high level of technical precision, physical fitness, and cognitive coordination (Candra, 2020; Digantara et al., 2020). Among the

various techniques in badminton, the smash is considered one of the most decisive and powerful attacking strokes. It is often used to finish rallies and score points quickly. The effectiveness of a smash is not solely dependent on the technique but also on specific physical attributes such as muscle power, coordination, and timing (Rahmat, 2021; Sahabuddin, 2023).

In the context of physical conditioning, explosive strength plays a critical role in badminton performance (Ricardo, 2023; Widiyanto et al., 2025). Specifically, the explosive power of the lower and upper limbs is essential for jump smashes, quick court movements, and powerful shot execution. Previous research has shown that leg power contributes to vertical take-off during smashes, while arm power influences the velocity and impact of the shuttle upon contact. Additionally, hand-eye coordination is vital in timing the racket swing to meet the shuttle accurately and efficiently.

A number of studies have examined the relationship between physical fitness components and performance in racket sports. For example, Ren et al., (2025) demonstrated the biomechanical demands of smashes in badminton, highlighting the importance of synchronized limb movements. More recent studies by Al-Selmi et al., (2025) have emphasized the role of neuromuscular qualities and reaction times in elite players. Despite these contributions, there remains limited empirical evidence that simultaneously evaluates multiple physical predictors and their combined effect on smash accuracy.

Most existing research tends to isolate one or two variables in relation to technical performance, such as upper limb strength or reaction time, without integrating the complex interplay among them. Furthermore, much of the literature focuses on elite-level athletes, often overlooking how these variables manifest in developmental or club-level players. This gap limits the generalizability of findings for coaches and trainers working with athletes in early performance stages (Akbari et al., 2023; Mahapatra & Pradhan, 2025; Saleh et al., 2024).

Another critical gap lies in the lack of attention to indirect effects and mediating relationships among physical components. For instance, while it is known that lower limb power contributes to jumping ability, its indirect effect on smash accuracy via upper limb activation has not been systematically examined. Similarly, hand-eye coordination may not directly affect power output, but could facilitate effective timing that supports upper limb explosiveness during shot execution.

This study addresses these gaps by exploring the direct and indirect effects of lower limb explosive power, hand-eye coordination, and upper limb explosive power on badminton smash accuracy (Hidayat et al., 2025; Rajab et al., 2025). The model used in this research incorporates both individual contributions and the structural relationship between the variables to explain performance outcomes more holistically.

The novelty of this research lies in its integration of multiple physical predictors within a single analytical framework using path analysis (Al-Selmi, Al Kikani, et al., 2025; Nisa'Urizka Fayogi et al., 2025). This approach allows for the examination of not only direct relationships but also how certain physical qualities influence one another and ultimately contribute to technical accuracy. Such insights are especially valuable for coaches seeking targeted physical training interventions that improve specific aspects of skill execution.

Therefore, this study aims to analyze the direct and indirect effects of lower limb explosive power, hand-eye coordination, and upper limb explosive power on the accuracy of badminton smashes among athletes of PB Cahaya Muda. The findings are expected to provide evidence-based

recommendations for physical conditioning programs that enhance technical performance in badminton through a better understanding of structural relationships among key motor variables.

METHODS

This study employed a quantitative associative research design with a path analysis approach to examine the direct, indirect, and simultaneous effects of lower limb explosive power, hand-eye coordination, and upper limb explosive power on badminton smash accuracy. The goal was to explore the structural relationships among these variables and determine their influence on technical performance in badminton.

The population of this study consisted of all 55 athletes registered at PB Cahaya Muda. From this population, 20 athletes were selected as the research sample using purposive sampling techniques. The selection criteria included athletes who were actively training and participating in matches, ensuring that the sample reflected individuals with relevant performance characteristics.

To measure the research variables, several standardized physical tests were utilized. Lower limb explosive power was assessed using the vertical jump test, which recorded the height of an athlete's jump as an indicator of leg power. Hand-eye coordination was measured through a coordination test involving visually guided motor tasks, requiring synchronization between vision and upper limb movements. Upper limb explosive power was evaluated using the one-hand medicine ball throw, which is widely accepted for measuring dynamic arm strength and power. The dependent variable, badminton smash accuracy, was tested through a targeted performance assessment, where athletes were instructed to execute smashes toward specific target areas. Scores were assigned based on the number of successful and accurate hits.

All test procedures were conducted under standardized conditions and supervised by trained personnel to ensure data reliability and validity. The collected data were analyzed using path analysis to examine the magnitude and direction of relationships among the variables. The statistical analysis was carried out with a significance level of $\alpha = 0.05$, allowing for the identification of both direct and mediated effects. The final model was evaluated using structural equation modeling techniques to determine the overall explanatory power of the predictor variables on smash accuracy.

RESULT AND DISCUSSION

This study aimed to examine the direct and indirect effects of lower limb explosive power, hand-eye coordination, and upper limb explosive power on badminton smash accuracy among athletes of PB Cahaya Muda. The analysis employed path analysis with a significance level of $\alpha = 0.05$.

Descriptive Statistics and Path Coefficients

The descriptive analysis revealed that athletes of PB Cahaya Muda displayed varied levels of physical fitness components. Vertical jump scores, medicine ball throw distances, and hand-eye coordination tests were used to measure the independent variables, while smash accuracy was assessed through technical execution tests in badminton. The path analysis results are summarized in Table 1 below:

Table 1. Direct and Indirect Effects of Variables on Smash Accuracy

Predictor Variable	Direct Effect	Indirect	Total	Contribution

	(β)	Effect	Effect	(%)
Lower Limb Explosive Power	0.435	–	0.435	18.92
Hand-Eye Coordination	0.057	0.0345	0.0915	3.49
Upper Limb Explosive Power	0.564	–	0.564	31.08
Indirect: Lower Limb → Upper Limb → Smash	–	0.886	0.886	78.49
Simultaneous Contribution	–	–	–	88.6

From Table 1, it is evident that upper limb explosive power has the highest direct effect (β = 0.564 or 31.08%) on smash accuracy, followed by lower limb explosive power (β = 0.435 or 18.92%). Meanwhile, hand-eye coordination showed a relatively low direct impact (β = 0.057 or 0.27%) and a minor indirect contribution via upper limb explosive power (0.0345 or 3.49%).

The strongest indirect path was found from lower limb explosive power through upper limb explosive power, contributing 78.49% to the overall effect. This indicates that while leg power alone is important, its influence is significantly channeled through upper limb activation in producing an effective badminton smash.

Table 2. Structural Model Summary

Model Fit Indicator	Value
R-Square	0.886
Significance Level	0.05
N (Sample Size)	20

Table 2 shows the R-square value of 0.886, indicating that 88.6% of the variance in badminton smash accuracy is explained by the three predictors combined (lower limb power, hand-eye coordination, and upper limb power).

Discussion

The findings support the hypothesis that physical components significantly influence badminton smash accuracy (Edmizal et al., 2023; Mangun & Subarkah, 2024). Explosive strength of the arms contributes most significantly, aligning with the biomechanical requirement for rapid arm extension and wrist snap during the overhead smash motion. This is consistent with previous research emphasizing the role of arm power in racket sports performance (Indora et al., 2022; Rahayu et al., 2024; Wang et al., 2025).

Lower limb explosive power also plays an important role, not only for jumping during jump-smashes but also for generating kinetic chain force transfer. However, its indirect effect through upper limb power suggests that proper strength integration between limbs is critical (Pratama, 2020).

Interestingly, hand-eye coordination, often emphasized in racket sports, showed limited direct influence (Ma et al., 2024). This could be due to the homogeneity of coordination skill levels among the sampled athletes, or that coordination becomes more prominent in game-specific contexts rather than isolated smashing.

These results suggest that targeted strength training, especially for the upper limbs, combined with integrated lower limb conditioning, can significantly enhance smash performance. Furthermore, coaches should still maintain coordination drills to support technical execution, even if its impact on raw smash accuracy is limited.

CONCLUSION

The results of this study conclude that the accuracy of badminton smashes among PB Cahaya Muda athletes is significantly influenced both directly and indirectly by the physical components examined. Upper limb explosive power has the strongest direct impact on smash accuracy, followed by lower limb explosive power, while hand-eye coordination shows minimal direct contribution. However, lower limb explosive power and hand-eye coordination both exert meaningful indirect effects through their influence on upper limb explosive power. Collectively, these three variables explain 88.6% of the variance in smash accuracy, indicating that improving physical components particularly arm strength can substantially enhance smash performance in badminton.

CONFLICTS OF INTEREST STATEMENT

Regarding this study, the author declares that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

Study concept and design: Ari Setiawan J. Acquisition of data: Wilda Welis. Analysis and interpretation of data: Ahmad Chaeroni. Drafting the manuscript: Ari Setiawan J. Critical revision of the manuscript for important intellectual content: Zulbahri Zulbahri. Statistical analysis: Ari Setiawan J.

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